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TENSILE AND FATIGUE BEHAVIOR OF TUNGSTEN/ COPPER COMPOSITES

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Work on W/Cu unidirectional composites was initiated to study the behavior of this ductile-ductile composite system under thermomechanical fatigue and to examine the applicability of fatigue-life prediction methods for thermomechanical fatigue of this metal matrix composite.

The first step has been to characterize the tensile behavior of four ply, 10 vol.% W/Cu plates at room and elevated temperatures. Since it is envisioned that unidirectional composites in service will likely see off-axis stresses, the tensile behavior of four fiber orientations are being studied: 0°, 5°, 15°, and 90° (where fiber orientation is the angle between the applied stress and the fiber direction). The 0° and 90° tests are the upper and lower bounds of tensile strength and modulus. The 5° and 15° tests are intermediate cases. Strain-controlled experiments at 25 and 260 °C have been performed to date. At 25 °C the tensile strength, yield strength, and modulus of the 0°, 5°, and 15° specimens were about the same. The 90° specimen had lower strengths and modulus. At 260 °C the strengths and the modulus were largest for the 0° specimen and decreased as the orientation angle increased. These properties were consistent with the rule of mixtures at both temperatures. The yielding behavior of the 0°, 5°, and 15° specimens was discontinuous at 25 °C but was smooth at 260 °C.

The fracture surfaces of the 0°, 5°, and 15° specimens had the same predominant features. Fiber pullout predominated, but, because of a very strong fiber-matrix bond, the W fiber surfaces have tightly adherred Cu matrix scales, covering about 20 to 25 percent of the fiber surface. Ductile microvoid coalescence prodominates in the copper matrix. Longitudinal sections of the failed specimens reveal that the fibers each have multiple breaks, up to 25 to 50 mm from the fracture surface. Upon closer examination, each individual fiber break is found to be two closely spaced fiber fractures.

The 90° specimens fail by transverse splitting of the fibers. The matrix between the fibers fails by ductile microvoid coalescence. The fibers remain very well bonded to the matrix, with no significant debonding even on the fracture surface. The fibers are all split up to 35 mm away from the fracture surface. Some of these splits start inside the fibers, away from the machined surface, although most of the observed fibers had at least one wide split, which extended across the width of the specimen.

Fatigue experiments were conducted in load control on 0° specimens at 260 °C. The maximum cyclic stress was varied but the minimum cyclic stress was kept constant. Cycle frequency was about 3 cpm, which gave strain rates similar to those used in the tensile tests. All tests were performed in vacuum.

The cyclic mean strain increased throughout the fatigue tests, suggesting that there may be a creep fatigue process controlling the failure. The elastic modulus remained constant until just before failure. The strain at failure increased with increasing maximum cyclic stress.

Future experimental work will include fatigue at 550 °C and thermomechanical fatigue between 260 and 550 °C. In addition, the availability of a 12-ply composite plate should enable fully reversed, strain-controlled fatigue to be performed. The applicability of currently available life prediction techniques to the data generated will be examined.

OUTLINE

1. MATERIAL AND TEST PROCEDURES
2. TENSILE BEHAVIOR
3. FATIGUE BEHAVIOR
4. SUMMARY
5. FUTURE WORK

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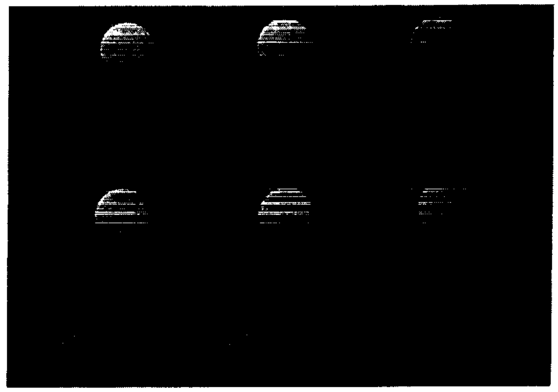
TUNGSTEN-FIBER-REINFORCED COPPER



500 μm

9 VOLUME PERCENT UNIDIRECTIONAL W FIBERS, 4 PLIES

MATRIX: OFHC COPPER, ASTM GRAIN SIZE #8-9
FIBERS: G.E. 218 W WIRE (0.008 in. DIAM.)

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TEST CONDITIONS

	TENSILE	FATIGUE
TEMPERATURE, $^{\circ}$C	25, 260	260
FIBER ORIENTATIONS	$0^{\circ}, 5^{\circ}, 15^{\circ}, 90^{\circ}$	0°
TEST CONTROL	STRAIN	LOAD
TEST RATE	2.0×10^{-4}/SEC	3 CPM
ENVIRONMENT	VACUUM	VACUUM

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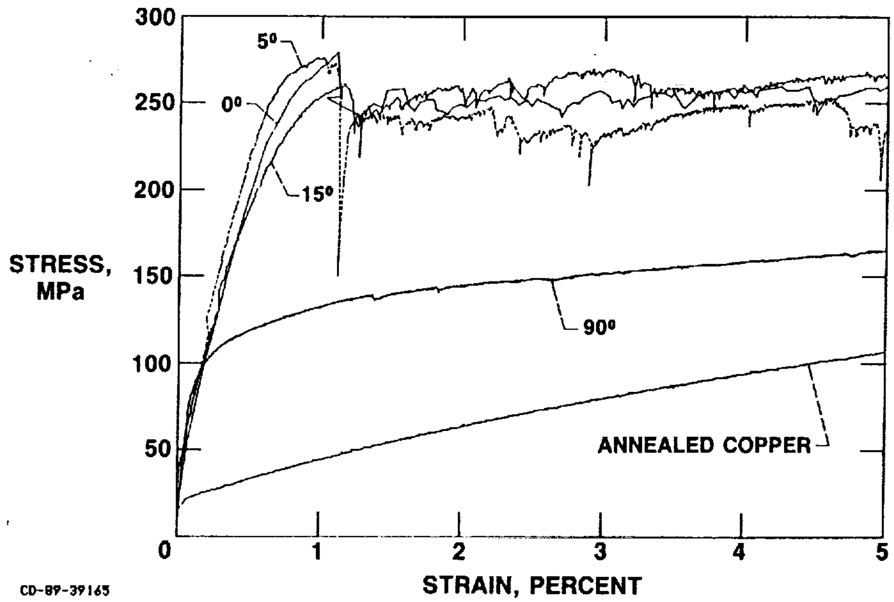
TENSILE DATA FOR 9 VOLUME PERCENT W/Cu

T = 25 °C



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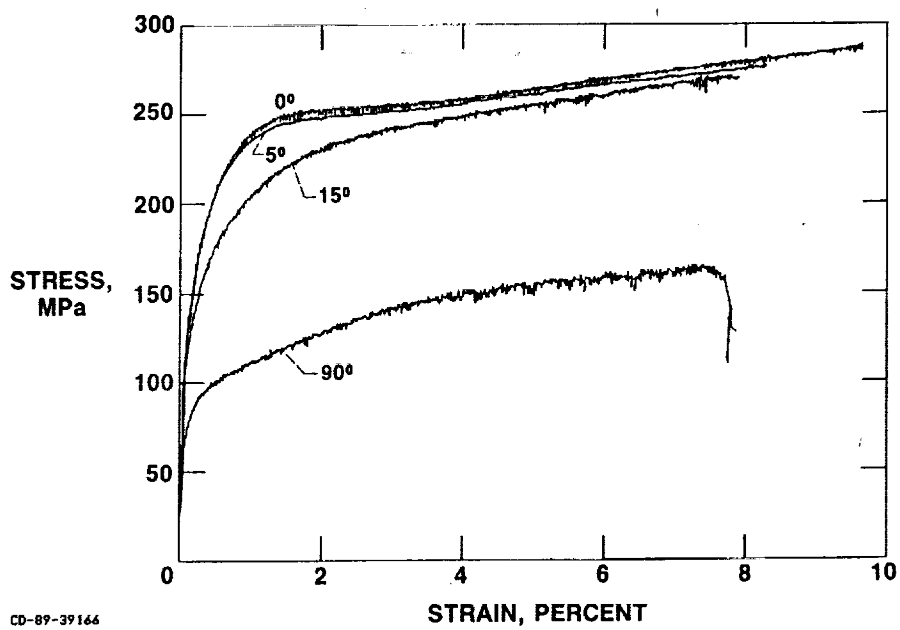
TENSILE DATA FOR 9 VOLUME PERCENT W/Cu

T = 260 °C



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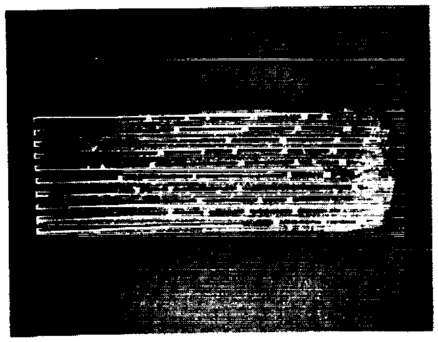
TENSILE FAILURE BEHAVIOR FOR W/Cu AT 25 °C

0°, 5°, AND 15° SPECIMENS

FIBER FRACTURES



5.6 X

PAIRS OF FIBER BREAKS

50 X

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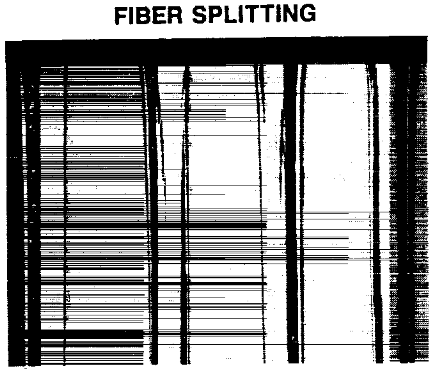
TENSILE FAILURE BEHAVIOR FOR W/Cu AT 25 °C

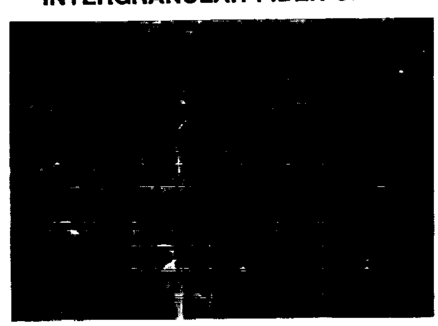
90° SPECIMEN

FIBER SPLITTING



50 X

INTERGRANULAR FIBER SPLIT



20 μm

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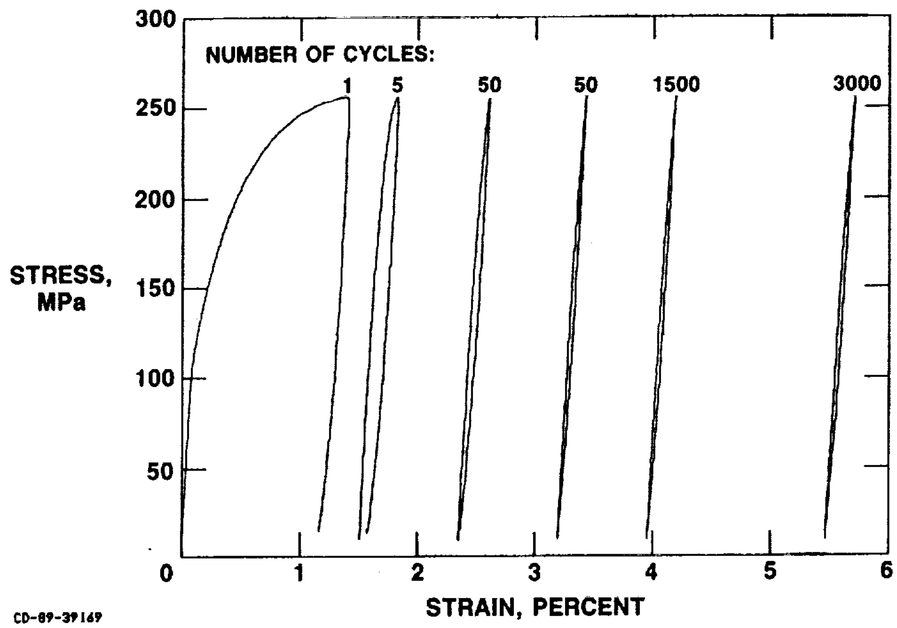
FATIGUE DATA FOR 9 VOLUME PERCENT W/Cu

T = 260 °C



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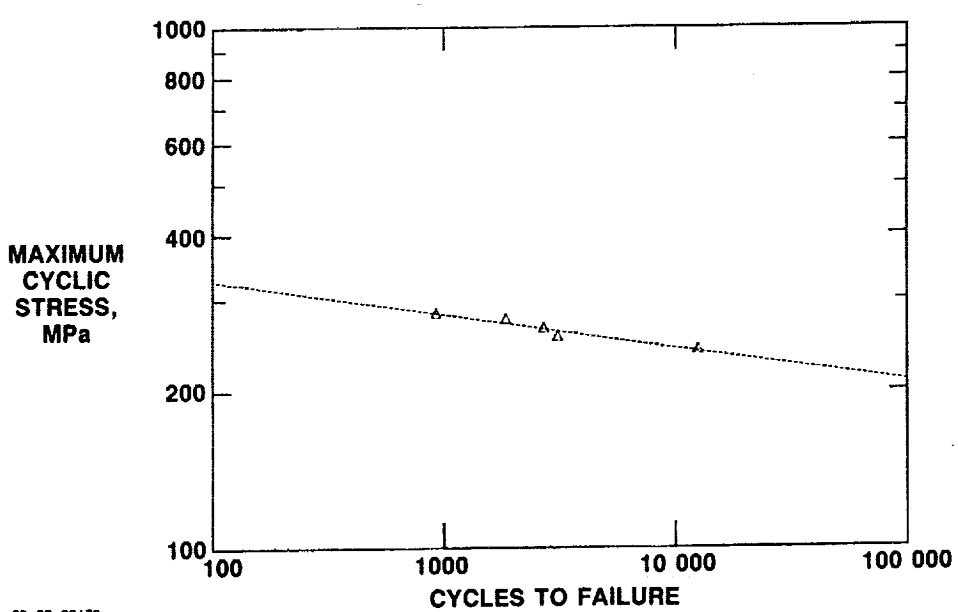
MAXIMUM CYCLIC STRESS VERSUS LIFE FOR FATIGUE OF 9 VOLUME PERCENT W/Cu

T = 260 °C



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SUMMARY

TENSILE BEHAVIOR

1. AT 25 °C, 0°,5°,15° SPECIMENS HAD THE SAME TENSILE PROPERTIES. THESE VALUES WERE CONSISTENT WITH RULE OF MIXTURES.
2. THESE SPECIMENS HAD DISCONTINUOUS YIELDING CAUSED BY PROGRESSIVE FIBER FAILURE.
3. AT 25 AND 260 °C THE TRANSVERSE (90°) SPECIMEN HAD THE LOWEST PROPERTIES. FAILURE AT 25 °C WAS CAUSED BY FIBER SPLITTING.

FATIGUE BEHAVIOR

1. CYCLIC MEAN STRAIN INCREASED CONTINUOUSLY TO FAILURE.
2. ELASTIC MODULUS REMAINED CONSTANT UNTIL FAILURE.
3. STRAIN AT FAILURE INCREASED WITH INCREASING MAXIMUM CYCLIC STRESS.

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FUTURE WORK

1. ISOTHERMAL FATIGUE AT 550 °C
2. THERMOMECHANICAL FATIGUE
3. FULLY REVERSED FATIGUE
4. LIFE PREDICTION

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